Networks of Science: Crossing Disciplines, Institutions and Sectors

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Today's Presentation

- Collaborative Nature of Science
- Growth of Virtual Organizations in Science
- Evaluating Collaborative Relationships in Science Using Social Network Approaches
- Current Data on Academic EAS Scientists and Their Networks
- Implications and Questions for ESIP

Science: Increasingly Collaborative and Cross Disciplinary

- Effective collaboration is a social process whereby researchers gain new “knowledge value” as a result of their interaction (Bozeman and Rogers, 2001.)
- Researchers learn and gain the skills and knowledge of other researchers through collaborative interactions. The “transfer of skills” is an important and primary benefit of research collaboration. (Katz and Martin,1987.)

Collaborative Relationships

Organizational and Structural Aspects

Technological Aspects

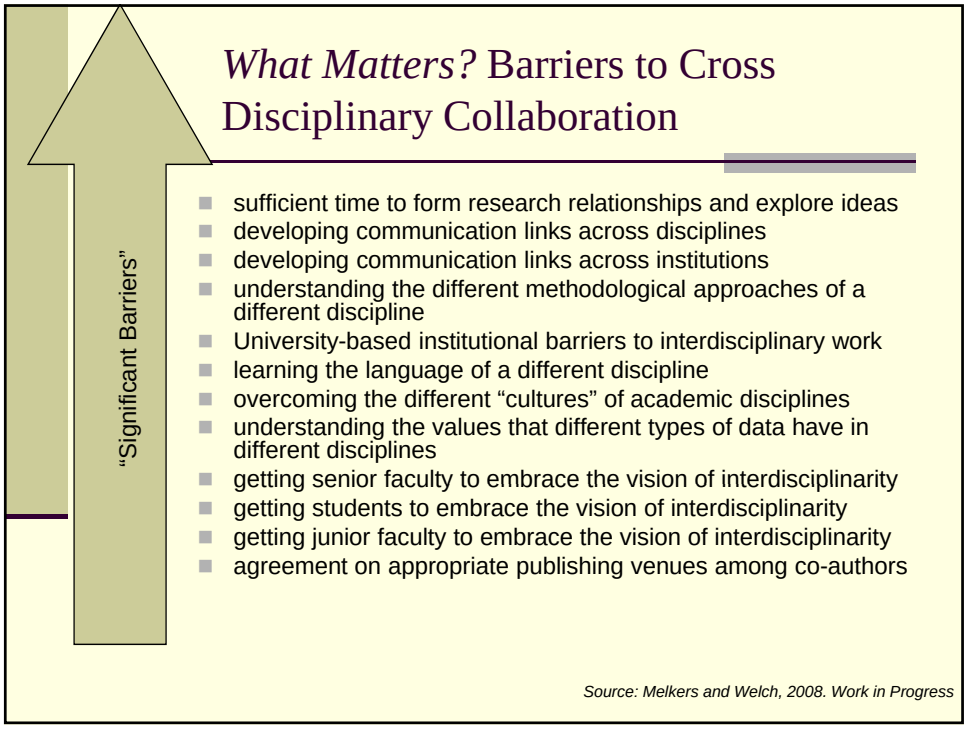
Human and Social Aspects

Why? The Value of Collaborative and Interdisciplinary Research

- Collaborative research has been shown to:
  - Encourage cross-fertilization across disciplines
    - (Beaver and Rosen, 1978, 1979a,b; Katz and Martin, 1997; Melin, 2000)
  - Provide access to expertise & resources
    - (e.g., Katz and Martin, 1997; Melin,2000; Melin, 2000; Thorsteinsdottir, 2000; Beaver, 2001; Clarke, 1967; Heffner, 1981)
  - Encourage learning tacit knowledge about a technique
    - (Beaver and Rosen, 1978, 1979a,b; Katz and Martin, 1997; Beaver, 2001)
  - Pool knowledge for tackling large and complex problems
    - (Maanten, 1970; Goffman and Warren, 1980; Thorsteinsdottir, 2000; Beaver, 2001)
  - Have a positive relationship with *productivity*
    - (e.g., Link and Bauer 1987; Link, Teece and Finan 1996; Thorsteinsdottir, 2000; Beaver,2001; Fox and Mohapatra 2007)
  - Have a positive relationship with quality and *impact of publication*
    - (e.g., Katz and Hicks, 1997; Oliver, 2004)
  - Contribute to prestige or visibility
    - (Crane, 1972; Beaver and Rosen, 1978, 1979a,b; Katz and Martin, 1997; Beaver, 2001),

Recognition of the Importance of Collaboration in Science

- BIG science and policy issues
  - Virtual Organizations have grown that reflect a growing exchange and relationship among organizations pursuing related scientific questions.
- National Science Foundation has shown a commitment and to cross-disciplinary research.
  - Significant increase in support for cross cutting research
  - Increase in expectation for integrated multi-disciplinary research teams.
  - Formalization of a program to support examination of virtual organizations.
    - The Virtual Organizations as Sociotechnical Systems (VOSS) program supports scientific research directed at advancing the understanding of what constitutes effective virtual organizations and under what conditions virtual organizations can enable and enhance scientific, engineering, and education production and innovation.



What Matters? Barriers to Cross Disciplinary Collaboration

- sufficient time to form research relationships and explore ideas
- developing communication links across disciplines
- developing communication links across institutions
- understanding the different methodological approaches of a different discipline
- University-based institutional barriers to interdisciplinary work
- learning the language of a different discipline
- overcoming the different "cultures" of academic disciplines
- understanding the values that different types of data have in different disciplines
- getting senior faculty to embrace the vision of interdisciplinarity
- getting students to embrace the vision of interdisciplinarity
- getting junior faculty to embrace the vision of interdisciplinarity
- agreement on appropriate publishing venues among co-authors

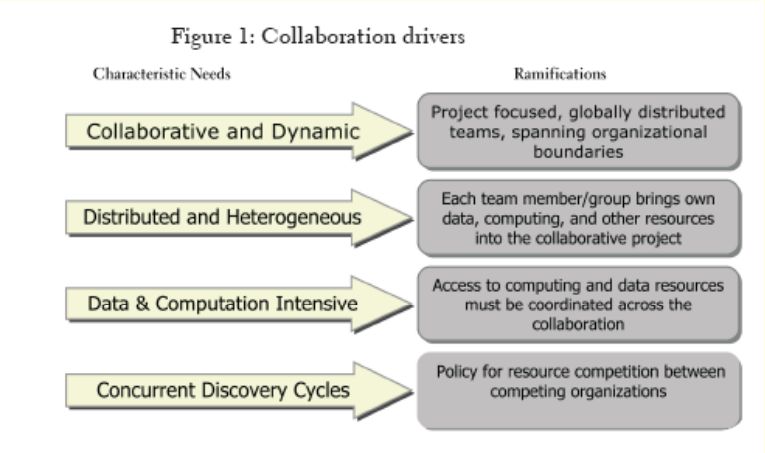
Source: Melkers and Welch, 2008. Work in Progress

Virtual organization [n]:
a collection of geographically distributed, functionally and/or culturally diverse entities that are linked by electronic forms of communication and rely on lateral, dynamic relationships for coordination [1].

[1] DeSanctis, G. and Monge, P. Communication Processes for Virtual Organizations. Organization Science, 10 (6). 693-703. 1999.

- A **Virtual Organization** is created by a group of individuals whose members and resources may be dispersed globally, yet who function as a coherent unit through the use of cyberinfrastructure. (NSF)

What drives Virtual Collaboration?



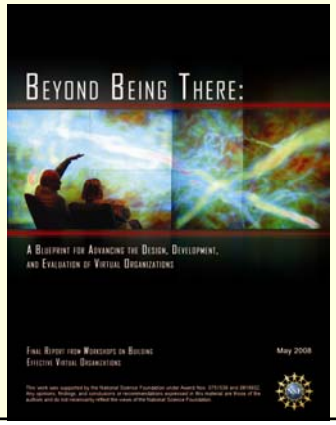
(Source: NSF, 2008.)

Problems and Barriers for VO's

- BOTH Individual and Organizational-level issues
- Some of the Challenges:
  - Communication barriers
  - Understanding issues across disciplines and sectors
  - Cultural barriers
  - Self interest
  - Trust
  - Institutional norms
  - Institutional policies and structures

Key Challenges for Virtual Organizations

- Communication (effective communication)
- Meeting the needs of involved individuals and organizations
- Incentives
- Rewards/payback
- Clarity of needs
- Clarity of participation



UNDERSTANDING THE NATURE OF COLLABORATION

Evaluating the Outcomes of Science

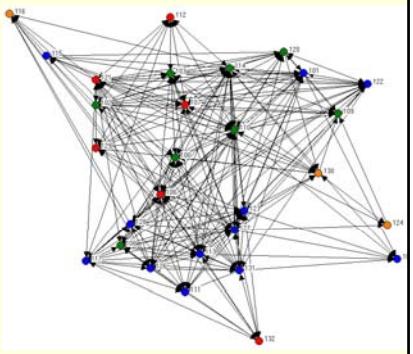
- Traditional approaches to the evaluation of scientific outcomes has relied on bibliometric, citation counts, and grant counts (Hicks, Breitzman et al. 2000; Chen and Hicks 2004; Geisler 2005; Li, Chen et al. 2007; Larsen 2008) .
- Increasing attention to the notion of **social capital** in science and the role of collaborative activities in building those resources (Bozeman and Dietz 2001; Bozeman and Corley 2004, Rhoten, 2007, Melkers and Welch, 2006, 2007).

Using Social Networks to Understand Collaborative Exchange

- Social network theory extends our inquiry to questions of:
  - Organizational Issues:
    - Network/service delivery effectiveness
    - Information use
  - Individual and Group-Related Issues
    - Interactions and collaboration between individuals and groups
    - Patterns of behavior
    - Ways in which networks are used to achieve particular ends
    - Relationship of network participation to desired ends

Common Network Characteristics

- Network Size
- Network Density
- Network Centralization
- Individual:
  - Centrality
  - Tie Strength
  - Betweeness
  - Position and Role
  - Multiplexity of Ties
  - among others……



Networks Matter for Collaboration & Reputation

For Example:

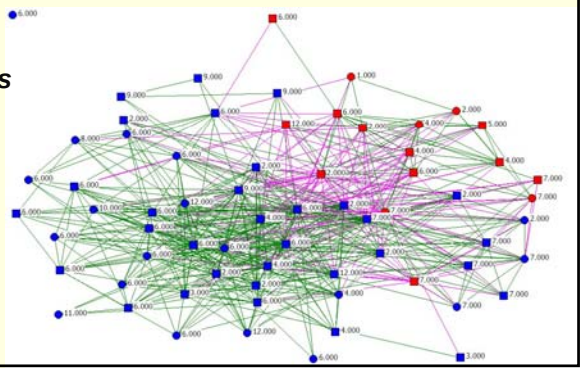
- Network Access is defined as an opportunity to participate in an established community of practice.
- Size: ideas and knowledge, know-how, complementary resources, awareness of opportunities, reputation and signaling, advice and support (Birley 1985; Stuart et. al. 1999; Shane and Cable 2002).
- Strength: weak ties for awareness, strong ties for trust (Granovetter 1973; Powell 1990)
- Structure: Brokerage v. solidarity (Burt 1992, 2005; Coleman 2003)
- Position and Hierarchy: Barrier and a mechanism for entrée and advancement (Long and Fox 1995, Burt, 1990)

Example: Interdisciplinarity in an NSF-ERC: Disciplinary Clustering

(From Survey Data)

- Barriers: Both engineers and social scientists point to issues of time, communication opportunities but also cultural factors in bridging disciplines. Institutional factors or lack of interest in interdisciplinary collaboration seldom noted.
- Facilitators: Respondents point to shared values, Center management, thrust leadership and the opportunities presented by shared projects.

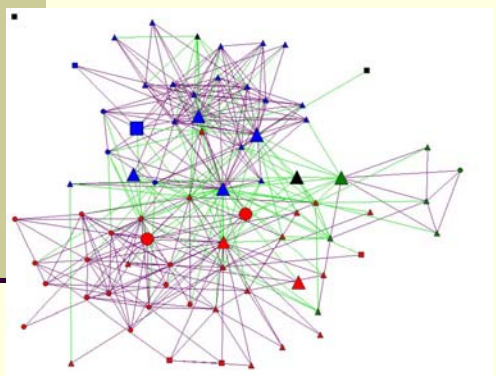
I understand this person's knowledge & research skills
(strongly agree answers only)



Legend:
Blue = Engineering
Red = Social Science
Circle = Junior faculty
Square = Tenured faculty

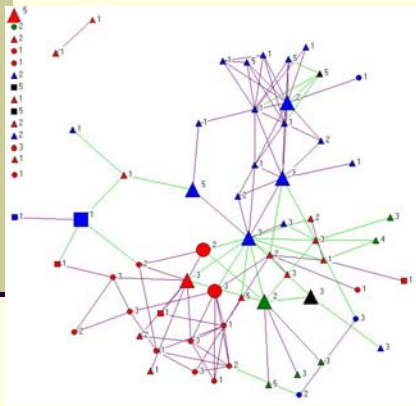
Green line = Within-discipline tie
Purple line = Cross-discipline tie

Example: Faculty Understanding of Each Other's Knowledge and Research Skills with Research Leadership Team Highlighted



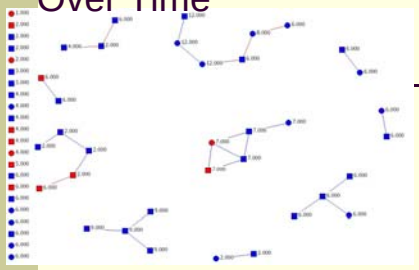
- Denser more complete network.
- Still dependent upon a small set of individuals who bridge disciplines and institutions.
- Leadership are not only faculty with interdisciplinary knowledge.
- Substantial potential for greater cross-disciplinary and cross-institutional interaction.

Example: Bridging Knowledge Networks (Scientists Who Report Close Ties, with Research Leadership Team Highlighted)

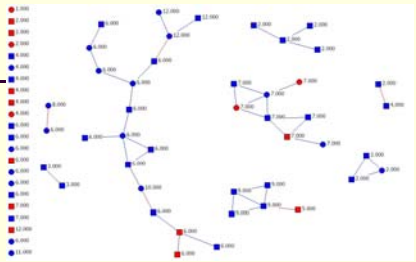


- Majority of cross institutional and cross disciplinary ties occur between a relatively small number of individuals.
- Many of these key individuals are members of the Research Leadership team.
- Potential lack of interdisciplinary and cross-institutional 'robustness' in the network.

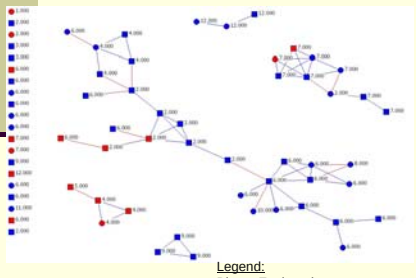
Example: Dynamic Elements: Network Relationships Over Time

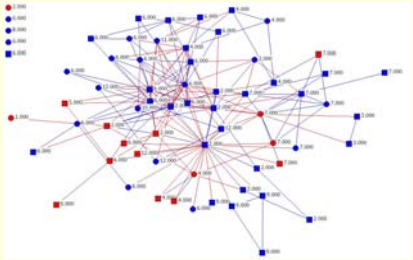


Pre and Since Center Co-Authorship



Pre and Since Center Proposals





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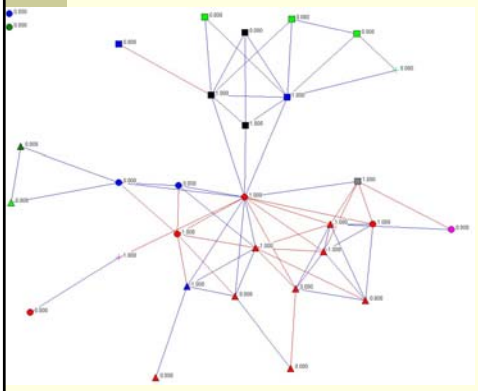
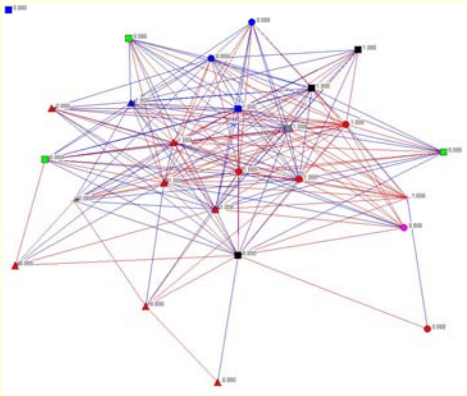
Example: Communication Networks in Collaborative Groups

Weekly Face-to Face Communication **Weekly Video Communication**



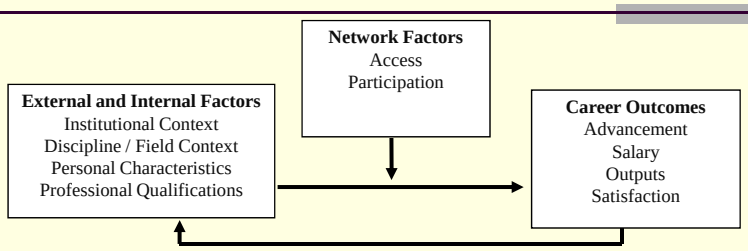


	Video	Email	Face-to-Face	Telephone	Non-work
Density	0.33	0.2	0.1	0.09	0.05
Avg. degree	11	9.6	4.2	5	2
Network Centralization	42%	40%	38%	53%	16%

WHAT IS THE NATURE OF THE COLLABORATIVE NETWORKS OF EAS SCIENTISTS?

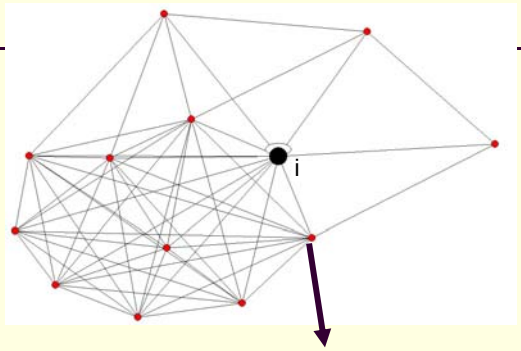
Julia Melkers and Eric Welch
Women in Science and Engineering: Network Access, Participation, and Career Outcomes

National Science Foundation (Grant # REC-0529642)



- ***How and why do networks make a difference in the career outcomes of women in STEM careers?***
  - Does network participation and access of men scientists significantly differ from that of women scientists?
  - Which factors predict the access and participation of scientists and engineers in both formal and informal networks?
  - How does the nature of scientists' networks have an impact on career outcomes?

Approach



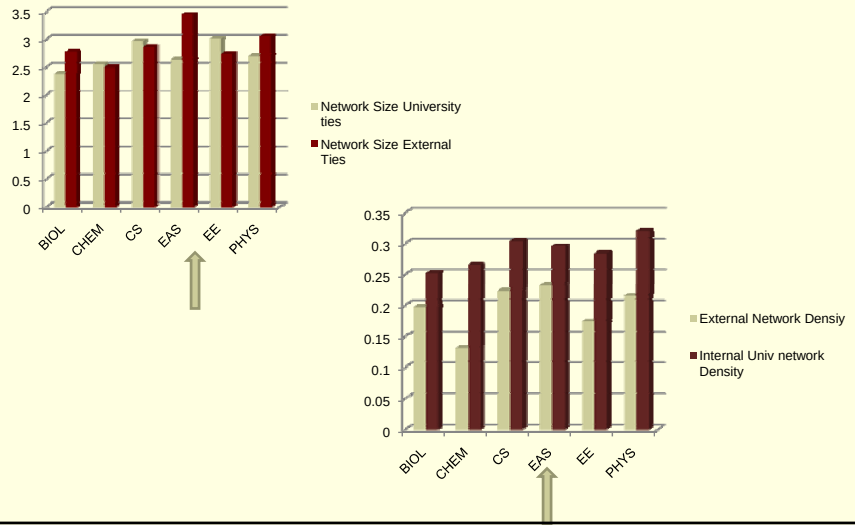
career outcomes$_i$ = ***f***(human capital vars$_i$, network variables$_i$, stratification vars$_i$, contextual vars$_i$)

Density | Homophily | Structural holes | …

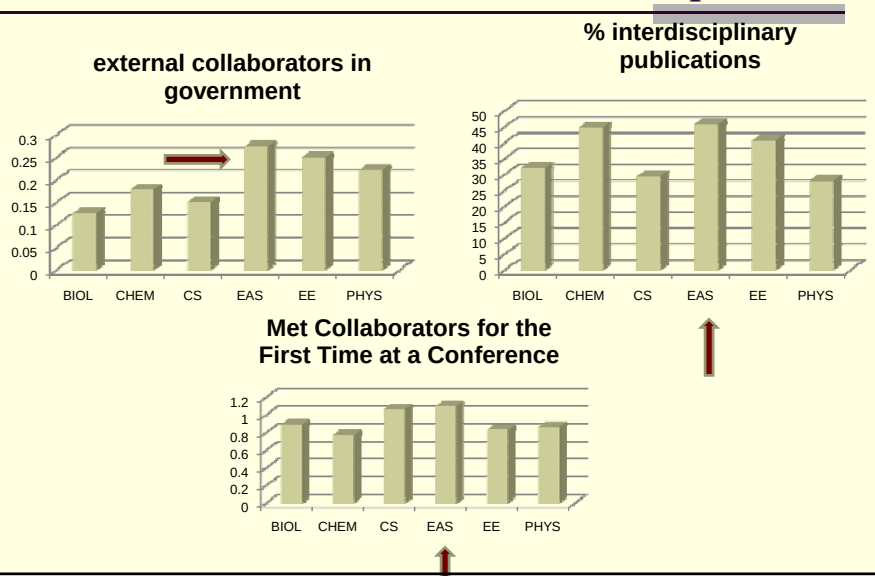
Sampling Frame

- Sample drawn from population of 25,000 faculty in Research I universities in the US
- Six fields: computer science, physics, electrical engineering, earth and atmospheric sciences, biology, chemistry
- Sample of 3500 stratified by rank, field and gender
- 1628 usable responses (47%)
- 54% women, 46% men
- 27% assistant, 28% associate, 45% full
- Relatively equal distribution of responses across fields by rank

Earth and Atmospheric Scientists in Research I Institutions: Mean Responses



Earth and Atmospheric Scientists in Research I Institutions: Mean Responses



ESIP: Realizing Our Potential.

- Examining *"where we have been and where we will go in our second decade toward realizing the potential of a collaborative, virtual consortium of Earth science data and applications professionals."*

Where has ESIP been and where is it going?

- Data Coordination?
- Data Dissemination?
- Collaboration?
- Meeting the data needs of researchers?
- Providing useful exchange with data producers?
- Developing effective ties between organizations? Individuals?
- *Pushing knowledge and practice in the use of Earth science data forward through effective exchange among ESIP partners?*

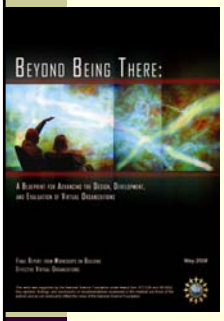
Guidance Based on Network Studies of Science and Virtual Orgs

- Focus on data integration, of course, but also address network issues.
- Give significant consideration to communication across ESIP
  - Semi-annual meetings
  - Electronic communication, overall and within subgroups
  - Assess technological communication platforms and their use
- Address institutional and disciplinary barriers to participation
  - Culture
  - Norms
  - Language
  - Data
- Consider layers of communication and interaction – multiple subgroups in ESIP
- Consider the dynamic nature of virtual organizations
- Consider individuals as bridges – postdocs, visitors, students, exchangeS.

Suggested Readings

Building Effective Virtual Organizations
An NSF Workshop
January 14th - January 16th, 2008

Great resources on NSF-BEVO website
Available at http://www.ci.uchicago.edu/events/VirtOrg2008/index.php?pg=reading



- Cummings, J., Finholt, T., Foster, I., Kesselman, C. and Lawrence, K. **Beyond Being There: A Blueprint for Advancing the Design, Development, and Evaluation of Virtual Organizations**.
- Foster, I., Kesselman, C. and Tuecke, S. ***The Anatomy of the Grid: Enabling Scalable Virtual Organizations***. International Journal of Supercomputer Applications, 15 (3). 200-222. 2001.
- DeSanctis, G. and Monge, P. ***Communication Processes for Virtual Organizations***. Organization Science, 10 (6). 693-703. 1999.
- Majchrzak, A., Jarvenpaa, S.L. and Hollingshead, A.B. ***Coordinating Expertise Among Emergent Groups Responding to Disasters***. Organization Science, 18 (1). 147-161. 2007.
- Cummings, J. N., & Kiesler, S., (2007). ***Coordination costs and project outcomes in multi-university collaborations.*** Research Policy, 36(10),1620-1634.
- Myers, J. ***Cyberinrastructure Lessons.***
- B. F. Spencer, Jr., Randal Butler, Kathleen Ricker, Doru Marcusiu, Thomas Finholt, Ian Foster, Carl Kesselman, ***Cyberenvironment Project Management: Lessons Learned*****.** whitepaper, September 5, 2006
- NRC. ***National collaboratories: Applying information technology for scientific research***, National Academy Press, Washington, D.C., 1993, See Page 7.
- Newman, M.E.J., D. J. Watts and Strogatz, S.H. ***Random graph models of social networks.*** Proceedings of the National Academy of Sciences, 99. 2566-2572. 2002.